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QUARTERLY PROGRESS REPORT

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Report No. 66-101-4
Contract NASw-417

BELLCOMM, INC.

QUARTERLY PROGRESS REPORT

July August September

1966

W. C. Hittinger
President

BELLCOMM, INC.

Washington, D. C.

Report No. 66-101-4
Contract NASw-417

QUARTERLY PROGRESS REPORT

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ABSTRACT

The activities of Bellcomm, Inc., during the quarter ending September 30, 1966 are summarized. Reference is made to reports and memoranda issued during this period covering particular technical studies.

BELLCOMM, INC.

Report No. 66-101-4
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BELLCOMM, INC.

QUARTERLY PROGRESS REPORT

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Table of Contents

APOLLO SYSTEMS ENGINEERING STUDIES

MISSION PLANNING

Apollo Flight Mission Assignments

An updated draft of the "Apollo Flight Mission Assignments" document was prepared and was subsequently approved and issued.

Contingency planning for the Apollo flights was reviewed and updated. A revised draft of the document, "Apollo Flight Program Description Including Contingencies," was submitted, subsequently approved and issued.

Lunar Landing Mission

A report was published on the introduction of an astronaut sleep period in lunar parking orbit prior to LM descent. (1) This evaluation is part of a continuing study of lunar surface operations and the integration of the lunar phases with other mission phases.

In cooperation with the Aerospace Environment Office at MSFC, a study was initiated to determine the extent to which environmental factors (weather) affect launch probabilities for lunar landing missions. Bellcomm has supplied detailed launch window/launch opportunity information based on trajectory calculations to MSFC.

A draft of "Criteria for Selection of Apollo Lunar Landing Sites" was completed. This document contains considerations involved in the selection of lunar sites for Apollo manned landings.

Vehicle Performance

A draft of the Quarterly Weight and Performance Report was submitted and subsequently issued in July. Drafts of the Monthly Weight and Performance Summary were submitted and subsequently issued during August and September.

Trajectory Analysis

Evaluation continued of the increase in free return lunar accessibility resulting from the addition of a plane change maneuver while in lunar parking orbit.

Work progressed toward determining the capability of the Apollo system to meet the pattern of initial and backup launch windows for the lunar landing missions. Investigation of the variation of translunar injection guidance parameters is under way to determine the feasibility of developing simplified guidance targeting.

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(1) Stay-Time Considerations for Early Lunar Landing Missions, Memorandum for File, D. R. Anselmo, July 15, 1966.

Guidance Analysis

Launch and entry guidance equations for AS-202 were studied, and the results were reviewed with MSFC and MSC.(2),(3) Similar studies on AS-204 are continuing.

A review of Apollo Digital Autopilot verification was conducted at the request of MSC. Recommendations for improving the effort were made.

A preliminary study on manual guidance of the launch vehicle was conducted and communicated to MSC.(4)

The final report on the guidance and navigation error analysis for a complete lunar mission was distributed.(5)

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(2) Capabilities of the Entry Guidance Equations for Mission AS-202. TR-66-310-5, I. Bogner, W. G. Heffron, August 9, 1966

(3) Description of Apollo Entry Guidance, TM-66-2012-2, I. Bogner, August 4, 1966.

(4) Manual Guidance to Circular Orbit, Memorandum for File, W. G. Heffron, August 18, 1966

(5) Summary of Apollo Guidance and Navigation Error Analysis, TR-66-310-4, D. A. Corey, T. S. Englar Jr., B. G. Niedfeldt, R. V. Sperry, July 6, 1966

REQUIREMENTS

Apollo Program Specification

A revised draft Appendix to the Apollo Program Specification for AS-207/208 was delivered to the Apollo Program Office Configuration Control Board. This appendix was subsequently approved and issued.

Discussions with the Centers on requirements for mission flexibility during prelaunch phases and LM final approach and landing capability are continuing.

Additional requirements covering real time mission alternates were prepared and forwarded to the Centers for comment.

Apollo Mission Sequence

A strategy for the LM powered descent and the effect of constraints imposed by hardware and operational requirements were examined.(6) A rationale was developed for variations in the landing strategy depending on the information available about the landing site. A revised Powered Descent and Landing Phase (Section 2.9) of the Apollo Mission Sequence Plan was prepared to reflect variations in the descent strategy.

The abort and real-time alternate mission capability and associated hardware and software capabilities being provided in the Apollo Program have been examined. A draft of "Apollo Abort and Real-time Alternate Mission Capabilities Description (U)" has been prepared.

Formulas were developed for estimating the probability of finding during lunar descent an obstacle-free interval on the lunar surface along a fixed straight-line flight path without lateral deviation.(7)

The operations planning for AS-204 was reviewed and a briefing on the mission sequence was given to the Apollo Program Director.

Mission Rules

Draft material was prepared for inclusion in the AS-205 Mission Rule Guidelines and additional draft material was provided for inclusion in the AS-501 Mission Rule Guidelines.

Apollo Ground Communication Network

An evaluation of the methods and procedures used for control of communications in the manned space flight network was distributed.(8) The report concluded that the

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(6) A LM Powered Descent Strategy, Memorandum for File, F. Heap, September 30, 1966

(7) Probability of Finding an Obstacle-Free Interval, TM-66-2023-5, P. Gunther, August 2, 1966

(8) Final Report, Evaluation of Methods and Procedures Used to Control the Manned Space Flight Ground Communications System, TR-66-320-3, J. E. Johnson, H. Kraus, June 30, 1966

existing method was effective; however, it also recommended some changes which would improve efficiency.

The analysis of the capabilities and limitations of the Communications, Command and Telemetry System (CCATS) (UNIVAC-494) at MCC-H is continuing. An algorithm for representing the character transfer and interrupt processing functions of the CCATS has been devised.(9)

Coverage Studies

A study was made to determine the coverage of long duration Earth orbital missions that could be provided by Unified S-Band (USB) stations at Canton, Kano and Tananarive. This study also included a review of equivalent coverage provided by an Apollo Instrumentation Ship.(10)

A previous study of USB System Tracking and Communications Coverage for 18 revolutions at differing launch azimuths has been revised to show coverage for the Apollo Manned Space Flight Network (MSFN) as it is now configured.(11)

A general summary of the results of coverage studies for Apollo missions has been prepared.(12)

Unified S-Band System (USB) Studies

An analysis was completed of the system noise temperature characteristics of the MSFN S-Band receiving equipment.(13) Equations were derived for predicting receiver noise temperature.

An analysis was performed of the communications links between the Apollo Space Vehicle and the MSFN during the post injection phase of the lunar mission.(14) The

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(9) Project Apollo-Communications, Command and Telemetry System - Analysis of Character Transfer and Interrupt Processing Functions, Memorandum for File, R. M. Marella, Bell Telephone Laboratories, Memorandum for File, August 9, 1966.

(10) Analysis of Additional Communications Coverage That Could be Obtained by Unified S-Band Stations at Canton Island Kano, and Tananarive, TM-66-2021-10, J. P. Maloy, August 30, 1966.

(11) Unified S-Band Tracking and Communications Coverage of the Manned Space Flight Network During Eighteen Earth Revolutions at 105 NM Altitude for Launch Azimuths at 72, 80, 90, 100 and 108 Degrees, Memorandum for File, J. P. Maloy September 20, 1966.

(12) Summary of Communications and Tracking Coverage Memoranda, TM-66-2021-11, J. P. Maloy, September 30, 1966.

(13) System Noise Temperature Characteristics of the Manned Space Flight Network S-Band Receiving Systems, TM-66-2021-7, R. L. Selden, July 1, 1966.

(14) Analysis of Communications Between the Apollo Space Vehicle and the MSFN During the Post Injection Phase of the Lunar Mission, TM-66-2021-12, H. Pinckernell, September 15, 1966.

analysis indicates that communications performance to both the CSM and S-IVB/IU should be adequate during this mission phase. Some masking of the vehicle antennas can be expected due to spacecraft attitude and this will result in short periods of time where communications performance will be marginal.

Bellcomm participated with MSC in review and revision of the plans for flight verification of the USB system during AS-202 and AS-204. The operation of the Merritt Island Launch Area (MILA) USB station was monitored during the AS-202 Mission and the results of the AS-202 USB test were reviewed with MSC.

Reentry Ship Communications

An evaluation of communication satellite terminal requirements for the Apollo Reentry Ship was completed. (15) It was shown that a 10 to 12 foot diameter antenna would provide acceptable voice communications and that the ship's C-Band radar antenna could be modified to provide this capability.

Electromagnetic Compatibility

A study of the methods and procedures used to control electromagnetic interference (EMI) in the Apollo Program concluded that adequate control was being obtained; however, the report also recommended some methods for improvement. (16)

Tracking Analysis

A study of the spectral energy density of noise components in radar tracking data was completed. (17) The data utilized in the study were that recorded by the FPS-16 radar at Bermuda during tracking of Gemini III, Gemini IV and Gemini V.

Flight Crew Performance

The study of one man and two man operation of the spacecraft continued with the identification of those aspects of nominal crew functions which might present problems during one man operation.

The development of a computer simulation of the task time-line of flight crew operations continued. Modifications were made to allow programming of optional tasks as well as mission-required tasks.

A review of biomedical and system factors (18) pointed out specific physiological, environmental, and subsystem limitations that could degrade astronaut performance

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(15) Communication Satellite Terminal Requirements on Apollo Reentry Ship, Memorandum for File, R. K. Chen, July 8, 1966

(16) Review of the Apollo Electromagnetic Compatibility Program, TR-66-320-1, A. G. Weygand, September 1, 1966

(17) Spectral Analysis of Noise in Radar Data, Memorandum for File, R. M. Scott, July 15, 1966

(18) Astronaut Performance During the Apollo Lunar EVA, TM-66-1011-3, A. N. Kontaratos, July 27, 1966

during lunar surface activities. Additional testing of suited astronauts using the Portable Life Support System (PLSS) under normal and off limit conditions was recommended, together with other systems checks and additional operational measurements. A joint position with Space Medicine and MSC Representatives recommended an increase of the total PLSS pressure from 3.7 to 3.9 psi.

Human Standards

A revised draft of the "Apollo Human Standards (Flight Crew)" document has been prepared and transmitted to MSC and to members of the Human Standards Working Group for comment.

Apollo Training

A study of the meteorological conditions at Houston, Texas over a five year period concluded that an estimate of 200 days per year of good Lunar Landing Training Vehicle (LLTV) flying weather is not an unreasonable figure; however, it probably represents an upper limit of the good weather to be obtained rather than an assured amount, or even an average amount.(19)

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(19) The Lunar Landing Training Vehicle - Effect of Local Meteorological Conditions: Houston, Memorandum for File, V. J. Esposito, September 23, 1966.

CONFIGURATION

Launch Systems

An evaluation was made of the results of an emergency egress exercise conducted by flight crew and ground crew personnel on a Block I CM mockup. A detailed examination of crew safety during the pre-launch period concluded that while certain hardware modifications would be completed in time for the AS-204 launch, both training and operational planning for pre-launch contingencies needed improvement.[20] The results of this study were presented to the Crew Safety Panel.

An analysis was made of the time factors associated with returning the Apollo/Saturn V space vehicle from the launch pad to the Vertical Assembly Building (VAB) at different points in the countdown in the event of a hurricane alert.[21]

Continuing the efforts on Apollo/Saturn V hold and recycle analysis, a study was made of the factors involved in defueling and decontamination of the CSM/LM propulsion systems after a prolonged hold on the launch pad. The results were discussed with MSC.

A memorandum was prepared accumulating the available information pertaining to the present spacecraft checkout automation concept and activities.[22]

The feasibility of adapting Apollo launch complexes to handle the launch of large solid rockets was investigated.[23]

Space Vehicle

A study was completed which provided an overall review of development problems in CSM subsystems.[24]

Status reports on CSM and LM technical problems were prepared for Apollo Program Office reviews. Special presentations were made during July on alternate tank configurations for the SM Reaction Control System and on the Extravehicular Mobility Unit.

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(20) Status Report: On-Pad Crew Safety, Memorandum for File, P. R. Knaff, L. G. Miller, M. M. Purdy, September 29, 1966.

(21) Apollo/Saturn V, Return to the VAB for Hurricane Alert, Memorandum for File, H. E. Stephens, July 11, 1966.

(22) Automation Development for SC Checkout, Memorandum for File, V. Muller, August 25, 1966.

(23) A Concept for Handling and Launching Large Solid Rockets, TR-66-330-2, G. W. Craft, A. W. Starkey, September 30, 1966.

(24) CSM Subsystem Problem Status, TM-66-2031-5, G. R. Huson, July 19, 1966.

A review of the implementation of the Emergency Detection System (EDS) in the launch vehicle and spacecraft was carried out in conjunction with the EDS subpanel of the Apollo Saturn Electrical panel.[25] During this review, a significant lack of redundancy in electrical connectors and wire routing in the launch vehicle was identified.

A study of the selection of Service Propulsion System (SPS) gimbal actuators for flights AS-501 and AS-502 was made as a contribution to a joint problem study with the Apollo Test Directorate.[26]

To support the Apollo Program Office in conducting the Design Certification Review for AS-204, a major effort was devoted to preparation of Launch Vehicle and Spacecraft Briefing Books for this flight.[27][28] These summarized the mission considerations and consumable usage planning, and provided descriptive material, configuration differences, and problem identification for each subsystem.

Spacecraft Computers

A study was made of methods for measuring the noise rejection capability of the logic circuits in the Block II Apollo Guidance computer and the LM computer. A presentation of the results of this study was given at MSC. Assistance was also provided to MSC with respect to qualification of parts for this equipment.

Apollo Computer Programming

A report on management control of computer programming was issued.[29] This report describes formal techniques to ensure the timely production and delivery of working, usable computer programs. These techniques are general enough to be applied to the variety of programming efforts existing in the Apollo Program.

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(25) Review of CSM Emergency Detection System at NAA, July 28, Memorandum for File, T. F. Loeffler, August 25, 1966.

(26) Selection of SPS Gimbal Actuators for Flights AS-501 and AS-502, Memorandum for File, J. J. O'Connor, July 15, 1966.

(27) AS-204 Design Certification Review - Mission Operations, Spacecraft, Briefing Book, September 16, 1966.

(28) AS-204 Design Certification Review - Mission Description, Mission Objectives, Launch Vehicle, Launch Complex, Briefing Book, September 1966.

(29) Procedures for Management Control of Computer Programming in Apollo, TR-66-320-2, B. H. Liebowitz, C. S. Sherrerd, E. B. Parker, III, September 28, 1966

SCIENTIFIC STUDIES

Space Environment

Lunar Surface

Analysis of the effect of lunar surface roughness on the amount of shadow cast by sunlight and on the infrared emission profile across the lunar disc was carried out.* Preliminary results suggest that the percentage of shadowed area can serve as a direct measure of mean surface slope, while roughness at infra-red wavelengths may explain the observed fact that limb temperatures at full moon are higher than predicted for a smooth Lambert sphere.

Lunar Surface Visibility Studies

Drawing on previous analysis of lunar photometry, recommendations have been made to MSC for the improvement of simulation aids for astronaut training, and for the study of lighting and reviewing conditions during a lunar landing.

Natural Environment and Physical Standards for the Apollo Program (NEPSAP)

During this quarter, a draft revision to the "Natural Environment and Physical Standards for the Apollo Program" (NEPSAP) was prepared, subsequently approved and issued. A significant item of change was a downward revision of the meteoroid model to reflect the results of the Pegasus series of meteoroid satellites. Several references and supporting documents were updated to include new and better data.

Radiation Environment

Dose rates were calculated for the AS-503 mission, which incorporates several high altitude orbits extending into the trapped radiation belts(30). Since the calculated doses are close to the tentative dose limits, operational methods of reducing the dose were suggested. One involves mission modification in response to the dose rate as monitored on-board. A second is to avoid the South Atlantic anomaly where most of the low altitude dose is acquired.

Site Survey

Lunar Orbiter

During the Lunar Orbiter I mission when no high resolution pictures were obtained, studies of off-nominal mission options were made. MSF inputs pertinent to

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* In conjunction with the TYCHO Space Science Study Group meeting in August at the University of California, San Diego.

(30) Radiation Levels on AS-503 Missions, Memorandum for File, R. H. Hilberg, July 11, 1966.

Apollo support were coordinated and relayed to the Langley Research Center (LRC) operations team at the Deep Space Operations Facility.

A study was carried out[31] recommending a technique of "calibration" of photointerpreters for rapid landing hazard analysis of Lunar Orbiter I data to optimize the targeting of Mission B for Apollo support.

A systems engineering study of computer analysis of Lunar Orbiter data to evaluate Apollo landing hazard has been completed.[32] Performance objectives were presented for a two-phase development, the first phase to achieve a minimal system with early availability and the second phase to achieve an augmented system with greater accuracy.

Other studies of the analysis of Lunar Orbiter data have continued. An evaluation of the effects of smear (about 30 meters) in the Lunar Orbiter I high resolution pictures has shown that the pictures can theoretically be enhanced to achieve a resolution of 5 meters in the smeared direction. A study of the application of computer analysis to the low resolution data in under way.

Surveyor

Crater distributions were measured from Lunar Orbiter photographs of the Surveyor I landing region and the target area for Surveyor B to estimate relative surface roughness. It was recommended that the Sinus Medi aim point be maintained, but that the trajectory be biased to a smoother area shown in the Lunar Orbiter photographs.

Experiments

Apollo Lunar Surface Experiment Package (ALSEP)

Continuing scientific support was given to MSC relative to the ALSEP Heat Flow Experiment. That support has recently been broadened to include the Lunar Surface Magnetometer, the Passive Seismic Experiment, the Active Seismic Experiment and the Suprathermal Ion Detector Experiment.

The requirement that the ALSEP operate while 100% covered with lunar dust was examined in the light of recent evidence on the nature of lunar surface material[33]. It was concluded that the lunar surface fragmental material is less cohesive than originally thought. The recommendation was made that, if necessary, the specification be relaxed incrementally so that first vertical and then other nonhorizontal

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(31) Lunar Orbiter Data Screening at Langley Research Center, Memorandum for File, D. D. Lloyd, August 16, 1966.

(32) Lunar Orbiter Photographic Data Analysis for Apollo Landing Hazard Appraisal, TR-66-340-3, C. S. Sherrerd, July 27, 1966.

(33) ALSEP Environmental Specification Revision: Lunar Dust, Memorandum for File, N. W. Hinners, September 22, 1966.

surfaces be considered dust free. Horizontal surfaces were to retain a 100% dust cover specification.

Lunar Geological Equipment

The desirability of carrying the Apollo Lunar Drill on early Apollo missions was examined(34). Currently associated with the Lunar Heat Flow Experiment on ALSEP Array B (for AS-506), the drill is a potentially valuable geologic tool. Additionally, it is desirable to test the drill in the lunar environment prior to commitment to the Heat Flow Experiment. Although now apparently precluded on AS-504 on account of weight limitations, it was recommended that the drill be a back-up experiment for AS-504 and AS-505.

Lunar Science Operations

Proposed AS-504 lunar surface mission tasks and timelines were examined(35). It was concluded that the primary and secondary scientific mission objectives could be met with a minimum of 8-13 man-hours of productive Extra Vehicular Activity (EVA) time or, nominally, two three-hour excursions per astronaut.

In view of all the assumptions and unknowns mission planners were urged to consider variable length excursions.

Contingency Study

A study is in progress to determine how to optimize the scientific return from Apollo lunar missions in off-nominal situations. Preliminary results on the feasibility of many experiments indicate that additional photographic and meteoroid collection experiments are likely candidates.

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(34) Apollo Lunar Drill - A Back-up Experiment for AS-504 and AS-505, Memorandum for File, N. W. Hinners, September 22, 1966

(35) Lunar Surface Stay Time for AS-504A, Memorandum for File, N. W. Hinners, August 9, 1966.

SPECIAL TASK ENGINEERING STUDIES

ASSISTANCE IN CERTAIN COMPUTER OPERATIONS AND RELATED ACTIVITIES

TASK ORDER NO. 12

During the period of July 1, 1966, through September 30, 1966, NASA usage of the 7044 computer was 3.34 hours. There was no independent usage (non-BCMSYS) of the 7040 computer for the period.

MANNED SPACE FLIGHT EXPERIMENTS PROGRAM STUDIES

TASK ORDER NO. 27

Disciplinary studies in Life Science, Earth Science and Resources, Lunar Science, and Physics were pursued. The recommendations and desires of authoritative groups (such as the National Academy of Sciences) are being summarized and compared with the known experiments proposed for manned space flight.

A number of additional experiment descriptions were added to the Manned Space Flight Experiment Catalog, the largest number being associated with early AAP experiment groupings, the Spent Stage Workshop, the Apollo Telescope Mount (ATM), and Applications A*.

* A passive package directed mainly to meteorology.

DATA PROCESSING FOR ADVANCED MANNED MISSIONS

TASK ORDER NO. 28

An initial set of data flow charts for a manned Mars flyby mission was prepared during this quarter. This effort will continue with increased emphasis on ground data processing and distribution.

During this period, a paper on functional requirements for spaceborne computers on advanced manned missions was prepared for presentation at the Electronic Research Center's seminar on spaceborne multiprocessing.

ADVANCED MANNED MISSIONS STUDIES (LUNAR)

TASK ORDER NO. 30

Work during the past quarter was conducted on a study of manned lunar program options. This study has been undertaken to examine, with an emphasis upon the vehicles and modules required, program options available in the period immediately after initial lunar exploration by the Apollo Program. A range of options was examined which is of lesser scope than permanent exploration or long staytime exploration systems yet of moderate sophistication and capability. The preliminary results of this study have been presented to the Advanced Manned Missions Program Office.

A study was also conducted on the use of an extendible boom erected vertically on the surface of the Moon as a communication systems antenna and a visual homing guide for astronauts roving within a prescribed area around a lunar base (LM shelter)(36). It appears that the use of a long inflatable boom (≃400 ft) is not feasible due to requirements to withstand the estimated meteoroid environment with a lightweight system. The use of a short boom (≃50 ft) does appear feasible for use as an effective means of realizing extended communication ranges; however, its use as a visual homing guide does not appear feasible.

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(36) A Study on the Use of an Extendible Boom as an Antenna/Homing Guide for Lunar Base Communication/Navigation Systems, Memorandum for File, C. E. Johnson, September 12, 1966.

GENERAL MISSION ENGINEERING STUDIES

Saturn/Apollo Applications Program Studies

Mission Planning

A preliminary analysis of Saturn Apollo Applications (SAA) mission 209 estimated flight performance was reported.[37] Mission requirements were found to exceed the available performance of the uprated Saturn launch vehicle. It was suggested that one method of easing these requirements is to lower the orbital altitude. This would necessitate adjustment of the launch date to permit the desired rendezvous with SAA-210.

Support was continued on MSF effort to develop an SAA experiment data flow plan. Responsibility has been assumed for two sub-tasks: (a) estimating experiment data generation and (b) coordination and assembly of the data plan.

Experiment S-027, a galactic X-ray sky survey experiment, was evaluated for inclusion in the Instrument Unit (IU) of the SAA-209. It was found that the IU location would severely limit the viewing angle of the S-027 detectors.[38] It was found further that if SAA-210, on which this experiment is currently scheduled is flown in the Apollo Program as a repeat of mission AS-208, the sensitivity of the experiment will be reduced by a factor of 1.4 if launched on schedule and could not be performed if launched 14 minutes late.[39]

Candidate experiments previously assigned for planning purposes to flights on the early SAA missions were further recommended for detailed assignments to specific spacecraft modules on the respective missions.[40] This work was done in support of MSFC payload integration activities.

For SAA launch profiles a graphical analysis was completed which predicts the impact point of the space vehicle following premature motor cut-off[41]. This problem

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(37) Flight Performance Estimate for SAA Mission 209, Memorandum for File, K. E. Martersteck, September 30, 1966.

(38) Installation of S-027 in the IU of Mission #209, Memorandum for File, T. C. Tweedie, Jr., July 21, 1966.

(39) Effect of Experiment S-027 Being Flown on AS-210 in the Apollo Program, Memorandum for File, T. C. Tweedie, Jr., July 19, 1966.

(40) Assignment of Experiments to Spacecraft Modules for Early SAA Missions, Memorandum for File, T. C. Tweedie, Jr., July 27, 1966.

(41) Instantaneous Impact Point Analysis, Memorandum for File, R. Y. Pei, July 13, 1966.

is one whose exact computational solution is lengthy and complicated. The graphical solution makes possible rapid trial calculations for the purpose of mission planning.

The program for computer aids to mission planning is now completed and is being debugged. After debugging, it will be applied to the problem of checking feasibility and preparing a time line for SAA-209. This mission has been chosen because considerable information is available about the experiments and also because the existing manual mission planning will provide a standard for comparison.

System Requirements

Work continued on the preparation of specifications with emphasis on the alternate mission SAA-209. The changes to the uprated Saturn I required for the orbital workshop mission were defined and presented to the Apollo Program Configuration Control Board.(42)

A study is underway to examine systems requirements for very long duration flights, using modified Saturn Apollo hardware. The study ground rules include a three-man crew, a single standard Saturn V for launch and the use of the spent S-IVB stage for habitability and system support.

System Configurations

The CSM, CSM/Rack, Spent Stage Experiment Support Module (SSESM, now called Airlock Module), Alternate Apollo Laboratory (AAL), and LM A-S/Rack spacecraft configurations were evaluated as potential experiment support systems for ATM Solar Astronomy, Applications A and Applications B* experiment packages.(43) Each of the three experiment groups was found to be compatible with all the configurations considered except:

A. A rigid mounting of the ATM experiments could not be accommodated in the SM Sector I because of insufficient volume for both the ATM and control moment gyros (CMG's).

B. The Applications B package could not be installed in either the SM Section I or the SSESM due to an insufficient weight capability.

The LRC System for Inertial Experiment Pointing and Attitude Control (SIXPAC) CMG system was found to have sufficient momentum storage capacity to meet the ATM pointing requirements for each configuration considered except the CSM/SSESM/S-IVB Workshop.

*Similar but more extensive than Application A.

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(42) Saturn IB Modifications Required to Support the Orbital Workshop Mission, Memorandum for File, M. S. Feldman, August 12, 1966.

(43) Comparison of Candidate SAA Experiment Support Modules, TM-66-1012-10, G. M. Anderson, D. J. Belz, P. W. Conrad, B. D. Elrod, W. W. Hough, J. Kranton, R. K. McFarland, T. C. Tweedie, J. E. Waldo, September 9, 1966.

More detailed configuration descriptions were developed for the ATM pointing control system,(44) LM A-S/Half-Rack/ATM(45) and CSM/Rack/ATM.(46)

A preliminary estimate was made of the mission durations obtainable with a CSM/Auxiliary Module/S-IVB Workshop launched by an Uprated Saturn I.(47) Graphs were developed from which mission durations can be estimated as a function of experiment payload and average electrical power requirements.

A study was made to define the modifications to an Apollo CSM that would permit its use for long duration earth orbital missions. It was determined that a CSM designed for a 125-day mission is within the payload capability of the Uprated Saturn I. By launching three such spacecraft in a sequence, it would be possible to support a crew of three astronauts in orbit for one year.(48)(49)

The Airlock Module (AM) was examined and found compatible as a support carrier for a group of Earth and atmospheric science experiments (Applications-A) to be flown on an early SAA mission.(50)

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(44) Description of a Pointing Control System for Hard Mounted Solar Astronomy Experiments, Memorandum for File, J. Kranton, July 12, 1966.

(45) LM A-S/Half-Rack Configuration for ATM Solar Astronomy Experiments, TM-66-1013-11, D. J. Belz, August 26, 1966.

(46) Configuration and Interface Description for ATM on a CSM/Rack, TM-66-1013-12, W. W. Hough, September 12, 1966.

(47) A Preliminary Estimate of Maximum Earth Orbital Mission Durations for a CSM/Auxiliary Module/S-IVB Workshop Configuration, TM-66-1013-8, D. J. Belz, July 12, 1966.

(48) CSM Configuration Study for One Year Mission to be Achieved by Rendezvous and Resupply (U), TM-66-1013-9, W. W. Hough, July 21, 1966, CONFIDENTIAL.

(49) Extended Lifetime Fuel Cell Status, Memorandum for File, W. W. Hough, August 5, 1966.

(50) Study of the AM for Support of Applications-A Group of Experiments, TM-66-1013-14, T. C. Tweedie, Jr., September 15, 1966.

During the quarter work was performed in support of MSF manned planetary mission studies. In particular attention was focused on a 1975 manned Mars flyby mission. Consideration was given to the flyby mission radiation and meteoroid environment, mission opportunities, and subsystem design problems. Principal areas of experimentation were defined, and unmanned probes were studied as the means of transporting experiments from the manned flyby spacecraft to the planetary environment.

Experiments Program

Experiment areas were defined to answer the major scientific and technological questions which could be explored during a Mars flyby mission. These areas were subdivided into en route and planetary encounter experiments. Encounter experiments either used on-board remote sensing equipment, or they utilized equipment delivered to the planet by unmanned probes. Several categories of probes, including orbiters, impacters, and landers were studied. In general it was found that a comprehensive set of experiments could be defined so as to make manned flyby a competitive mode of planetary exploration.

Experiments

One of the key scientific questions the manned flyby mission proposes to answer concerns the possibility of life on Mars. To implement this a Mars Surface Sample Return (MSSR) probe concept was studied as a technique for collecting a sample of the Martian surface and returning it to the manned spacecraft. (51) The advantages of early bioanalysis of the sample in a laboratory aboard the manned vehicle compared to remote, unmanned analysis at the Mars surface were evaluated.

The capability of telescopic photography of Mars from the manned flyby vehicle during a 1975 mission was examined. (52) It was concluded that the combination of a 1 meter diffraction limited telescope and a 5 meter focal length camera using 300 lines/mm film would be capable of photographing most of the planet at resolutions greater than 1 km. These full planet photographs would provide the stereo data necessary to derive the planet shape.

The optimum telescope design for long range photography of the entire planet was found to conflict with the optimum design for photographing a small portion of the

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(51) A Proposal for Sample Acquisition During a Manned Flyby Mission to Mars, Memorandum for File, A. N. Kontaratos, C. A. Pearse, July 20, 1966.

(52) Mars Flyby Photography, Memorandum for File, W. L. Piotrowski, July 25, 1966.

surface from the point of closest approach.[53] It was therefore recommended that the telescope be designed for long range photography because the penalty paid during encounter photography is one of decreased field of view rather than decreased resolution.

A conceptual design of a high resolution optical telescope compatible with the Mars flyby mission requirements was formulated.[54] Optics and pointing accuracy were considered primarily where there was a direct bearing on fundamental design philosophy. A separate smaller panoramic camera system to be used for encounter photography was studied.[55] This camera can achieve nearly the resolution of the large telescopic system with an order of magnitude increase in area coverage.

Areas of investigation other than photography include in situ measurements of the Martian atmosphere and surface properties. Experiments and possible probe delivery systems for the atmospheric measurements were studied,[56] and the advantages of slow descent vs. rapid ablative entry were evaluated in terms of validity of data. An instrument package with weight and data rates was proposed.

A geophysical instrument payload to be carried on a Mars surface lander was discussed[57] in terms of objectives, experiments, mission profile, telemetry requirements, and weight. The experiment list was drawn from those proposed for Surveyor and ALSEP with the added emphasis on surface atmospheric properties.

The 1975 Mars flyby mission would involve a 2 year trip around the sun out to a maximum distance of 2.2 A.U. This would present some unique opportunities for scientific exploration. An astronomer's timeline was written for this mission which listed the closest points of approach to the major planets and several asteroids.[58] A general description of the en route experiments program has been provided in draft form to MSF. The fields of interest considered were physics, astronomy, and the biosciences. Particular attention was paid to experiments which would take advantage of the trajectory of the flyby mission.

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(53) Design of a Telescope for a Mars Flyby Mission, Memorandum for File, D. B. James, July 20, 1966.

(54) Conceptual Design of a High Resolution Optical Telescope for Planetary Flyby Missions, Memorandum for File, M. H. Skeer, July 29, 1966.

(55) Photography of Mars Near Encounter on a Flyby Mission, Memorandum for File, D. B. James, August 19, 1966.

(56) Martian Atmosphere Experiments for Early Missions, Memorandum for File, F. G. Allen, P. L. Chandeysson, A. E. Hedin, August 10, 1966.

(57) Geophysical Instrument Payloads for a Manned Mars Flyby Mission, Memorandum for File, W. B. Thompson, July 21, 1966.

(58) Astronomical Timeline for 1975 Twilight Mars Flyby Mission, Memorandum for File, H. S. London, August 17, 1966.

Experiment Delivery Systems (Probes)

The Mars Surface Sample Return (MSSR) probe concept was examined for basic structural and propulsion feasibility.[59] Further preliminary design work on the MSSR submitted in draft form to MSF described a 12,000 lb vehicle capable of returning about 2 lbs of surface material in sealed containers to the flyby spacecraft.

Photographic probes designed to be launched to Mars from the manned flyby vehicle were discussed in terms of system description and probe mission profile[60]. Photography and TV systems for surface impacters, orbiters, and lander probes were considered.

Engineering studies of the Mars probes are of importance due to the relatively high weight growth factors and large volumes involved. These translate into payload penalties for the manned spacecraft. A discussion of propulsion and weight requirements for a Mars orbiter probe deployed from the flyby vehicle was provided for the cases of purely propulsive braking[61] and for atmospheric skipout plus propulsive braking[62] for a 750 lb payload. Atmospheric braking can reduce probe gross weight by as much as 50% to 75%.

Generalized growth factors were established for unmanned probes entering the Martian atmosphere.[63] Specific probes were sized to soft land a 1400 lb and a 350 lb payload, and to deliver a 45 lb payload for atmospheric sampling. Parametric plots were presented to illustrate the relationship between the physical parameters of typical entry probes and their influence on guidance and terminal deceleration systems.[64]

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(59) Conceptual Design of Structural and Propulsion Systems for an MSSR Rendezvous Vehicle, Memorandum for File, D. Macchia, M. H. Skeer, J. Wong, August 5, 1966.

(60) Feasibility of Photographic Probes to be Launched from a Manned Flyby Vehicle, Memorandum for File, E. M. Grenning, July 7, 1966.

(61) Velocity and Weight Requirements for Mars Orbiter Deployed from Manned Flyby, Memorandum for File, H. S. London, July 11, 1966.

(62) Atmospheric Braking of an Unmanned Mars Orbiter, Memorandum for File, D. E. Cassidy, September 29, 1966.

(63) Unmanned Entry Probe Sizing for a 1975 Manned Mars Flyby Mission, Memorandum for File, D. E. Cassidy, July 11, 1966.

(64) Some Considerations for Reducing the Size of Unmanned Mars Entry Probe Packages, Memorandum for File, D. E. Cassidy, July 28, 1966.

Spacecraft and probe trajectories in the vicinity of Mars have been computed for the 1975 flyby mission.(65) It was shown that early probe arrival may be achieved with minimal ΔV penalty.

Mission Environment

Radiation shielding requirements for manned interplanetary missions to Mars have been examined based on current Apollo dose limit guidelines(66). It was concluded that a shield of 10 g/cm^2 should be sufficient during solar cycle minimum. Somewhat thicker shielding may be required during solar maximum. However, the establishment of reliable dose limits is somewhat in question. A review of current information on the biological effects of ionizing radiation on man(67) concludes that available data are not adequate to justify the proposed radiation dose limits for interplanetary manned space flights.

A model meteoroid environment for a Mars flyby mission was identified and discussed.(68) Extrapolation from catalogued asteroids implies a flux at 2 A.U. that may be 4 or 5 orders of magnitude higher than the cometary meteoroid flux near earth. Direct measurements by an Explorer-type satellite could define the environment to a much higher level of confidence than is now possible.

Mission Opportunities

A study of a Venus swingby mode as a class of manned Mars mission was completed.(69) This mode could be used as a technique for reducing the required mass in initial earth orbit. The results were presented to the Space Flight Mechanics Conference of the American Astronautical Society on July 8, 1966 at the University of Denver.

Subsystem Design

Communications requirements for telemetry links were examined.(70) The study concluded that megabit data rates should be available for transmission from the manned

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(65) 1975 Mars Flyby Mission - Trajectories of Probes from Manned Spacecraft, Memorandum for File, J. J. Schoch, July 6, 1966.

(66) Radiation Shielding Needed for Extended Interplanetary Missions, Memorandum for File, R. H. Hilberg, August 11, 1966.

(67) Radiation Dose Levels for Manned Space Flight, Memorandum for File, A. N. Kontaratos, July 25, 1966.

(68) Meteoroid Hazard for Planetary Missions, Memorandum for File, J. S. Dohnanyi, July 25, 1966.

(69) Venus Swingbys for Manned Mars Missions During the 1978-1986 Period, Memorandum for File, A. A. VanderVeen, August 9, 1966.

(70) Communication Systems Design for Manned Mars Flyby Mission, TM-66-2021-8, R. K. Chen, R. L. Selden, July 29, 1966.

module to earth, with kilobit rates from the probe experiment packages direct to earth. Higher data rates could be maintained between the probes and the flyby module for the first 10 days after encounter.

Computer-driven integrated displays were suggested as a technique for improving man-machine interfaces in advanced manned missions. (71)

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(71) Man-Machine Interface Problems on Planetary Flybys, Memorandum for File, R. T. Kleiner, J. M. Nervik, P. S. Schaenman, August 23, 1966.

TRAJECTORY PROGRAMS

In connection with detailed investigation of planetary probe trajectories it has been necessary to improve the Bellcomm computer trajectory program. Two memoranda have been published describing improvements to trajectory optimization computation techniques. (72)(73)

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(72) Improvement to the Secant Method, Memorandum for File, J. J. Schoch, R. T. Yuill, September 27, 1966.

(73) Secant Hypersphere Approximation of "Gradient Methods" for n-dimensional Function Optimization, Memorandum for File, TM-66-1021-5, P. F. Long, J. J. Schoch, September 30, 1966.

COMPUTER PROGRAM STANDARDIZATION

A draft of "Procedures for Computer Program and Telemetry Data Resource Sharing" was transmitted to NASA for review. These procedures were developed in coordination with the MSF Resources Sharing Panel.

ENGINEERING SUPPORT

Computing Facility

Two changes were made during the report period to BCMSYS, the Bellcomm operating system for the IBM 7040/7044 system. User flexibility in referencing data files has been enhanced by permitting subjobs to be referenced by user-assigned numbers. Operating system efficiency has been increased by making available multiple relocatable libraries at execution time, which provides greater speed in the execution of the system loader.

The applications programming staff members assisted various Bellcomm groups in areas such as:

(1) General Purpose Data Storage and Retrieval System

(2) Apollo Communications System Capability

(3) Computer-Drawn Flow Charts

(4) LM Auto-Pilot Simulation

(5) Lunar Landing Site Selection

(6) Terrain Analysis for LM Guidance

(7) LM Toppling Study

(8) ΔV Requirements of Instrumented Probe from Mars Flyby Vehicle

(9) Time Line Analysis for SAA Mission Planning

(10) Spacecraft Weight and Sensitivities Program

(11) Computation of Interplanetary Transfer Trajectories

(12) CM Fuel Cell Thermal Study

(13) Launch Window Analysis for Interplanetary Missions

(14) Digital Processing of Lunar Orbiter Photographs

(15) Dynamic Analysis of Control-Moment-Gyro Stabilized Spacecraft

(16) Mars Probe Rendezvous Error Analysis

The following is a list of major study areas for which programs were completed during this quarter:

(1) Targeting and Trajectory Program

(2) Earth Radiation Belt Display

(3) Escape from Elliptical Orbit

(4) Penetration of a Spherical Penetrometer

(5) Tracking and Communication Coverage for SAA Mission

(6) Cross-Track Landing Site Position Determination

(7) Gravity Gradient Torques on Satellite Attitude

ADMINISTRATIVE

Contract and Financial

During September negotiations with NASA concerning the statement of work, estimated cost and fixed fee, man-years, and related subjects were completed for the fifth contract period (October 1, 1966, through September 30, 1967). An amendment to the contract covering these matters was executed on October 5, 1966.

Personnel

Effective September 1, 1966, W. C. Hittinger was elected President of Bellcomm replacing J. A. Hornbeck who became President of Sandia Corporation.

LIST OF REPORTS AND MEMORANDA

(Listed in Order of Report Date)

This index includes technical reports and memoranda reported during this period covering particular technical studies.

The memoranda were intended for internal use. Thus, they do not necessarily represent the considered judgment of Bellcomm which is reflected in the published Bellcomm Technical Reports.

TITLE	DATE
Final Report Evaluation of Methods and Procedures Used to Control the Manned Space Flight Ground Communications System, TR-66-320-3, J. E. Johnson, H. Kraus	June 30, 1966
System Noise Temperature Characteristics of the Manned Space Flight Network S-Band Receiving Systems TM-66-2021-7 R. L. Selden	July 1, 1966
1975 Mars Flyby Mission - Trajectories of Probes from Manned Spacecraft, Memorandum for File, J. J. Schoch	July 6, 1966
Summary of Apollo Guidance and Navigation Error Analysis, TR-66-310-4, D. A. Corey, T. S. Englar, Jr., B. G. Niedfeldt, R. V. Sperry	July 6, 1966
Feasibility of Photographic Probes to be Launched from a Manned Martian Flyby Vehicle, Memorandum for File, E. M. Grenning	July 7, 1966
Communication Satellite Terminal Requirements on Apollo Reentry Ship, Memorandum for File, R. K. Chen	July 8, 1966
Radiation Levels on AS-503 Missions, Memorandum for File, R. H. Hilberg	July 11, 1966
Velocity and Weight Requirements for Mars Orbiter Deployed from Manned Flyby, Memorandum for File, H. S. London	July 11, 1966
Unmanned Entry Probe Sizing for a 1975 Manned Mars Flyby Mission, Memorandum for File, D. E. Cassidy	July 11, 1966
Apollo/Saturn V, Return to the VAB for Hurricane Alert, Memorandum for File, H. E. Stephens	July 11, 1966

TITLE	DATE
Description of a Pointing Control System for Hard Mounted Solar Astronomy Experiments, Memorandum for File, J. Kranton	July 12, 1966
A Preliminary Estimate of Maximum Earth Orbital Mission Durations for a CSM/Auxiliary Module/S-IVB Workshop Configuration, TM-66-1013-8, D. J. Belz	July 12, 1966
Instantaneous Impact Point Analysis, Memorandum for File, R. Y. Pei	July 13, 1966
Selection of SPS Gimbal Actuators for Flights AS-501 and AS-502, Memorandum for File, J. J. O'Connor	July 15, 1966
Stay-Time Considerations for Early Lunar Landing Missions, Memorandum for File, D. R. Anselmo	July 15, 1966
Spectral Analysis of Noise In Radar Data, Memorandum for File, R. M. Scott	July 15, 1966
Effect of Experiment S-027 Being Flown on AS-210 in the Apollo Program, Memorandum for File, T. C. Tweedie, Jr.	July 19, 1966
CSM Subsystem Problem Status, TM-66-2031-5, G. R. Huson	July 19, 1966
A Proposal for Sample Acquisition During a Manned Flyby Mission to Mars, Memorandum for File, A. N. Kontaratos, C. A. Pearse	July 20, 1966
Design of a Telescope for a Mars Flyby Mission, Memorandum for File, D. B. James	July 20, 1966
Geophysical Instrument Payloads for a Manned Mars Flyby Mission, Memorandum for File, W. B. Thompson	July 21, 1966
Installation of S-027 in the IU of Mission #209, Memorandum for File, T. C. Tweedie, Jr.	July 21, 1966
CSM Configuration Study for One Year Mission to be Achieved by Rendezvous and Resupply (U), TM-66-1013-9 W. W. Hough, CONFIDENTIAL	July 21, 1966
Radiation Dose Levels for Manned Space Flight, Memorandum for File, A. N. Kontaratos	July 25, 1966
Mars Flyby Photography, Memorandum for File, W. L. Piotrowski	July 25, 1966

TITLE	DATE
Meteoroid Hazard for Planetary Missions, Memorandum for File, J. S. Dohnanyi	July 25, 1966
Assignment of Experiments to Spacecraft Modules for Early SAA Missions, Memorandum for File, T. C. Tweedie, Jr.	July 27, 1966
Astronaut Performance During the Apollo Lunar EVA, TM-66-1011-3, A. N. Kontaratos	July 27, 1966
Lunar Orbiter Photographic Data Analysis for Apollo Landing Hazard Appraisal, TR-66-340-3 C. S. Sherrerd	July 27, 1966
Some Considerations for Reducing the Size of Unmanned Mars Entry Probe Packages, Memorandum for File, D. E. Cassidy	July 28, 1966
Conceptual Design of a High Resolution Optical Telescope for Planetary Flyby Missions, Memorandum for File, M. H. Skeer	July 29, 1966
Communication Systems Design for Manned Mars Flyby Mission, TM-66-2021-8 R. K. Chen, R. L. Selden	July 29, 1966
Probability of Finding an Obstacle - Free Interval, TM-66-2023-5, P. Gunther	August 2, 1966
Description of Apollo Entry Guidance, TM-66-2012-2, I. Bogner	August 4, 1966
Extended Lifetime Fuel Cell Status, Memorandum for File, W. W. Hough	August 5, 1966
Conceptual Design of Structural and Propulsion Systems for an MSSR Rendezvous Vehicle, Memorandum for File, D. Macchia, M. H. Skeer, J. Wong	August 5, 1966
Capabilities of the Entry Guidance Equations for Mission AS-202, TR-66-310-5, I. Bogner, W. G. Heffron	August 9, 1966
Lunar Surface Stay Time for AS-504 A, Memorandum for File, N. W. Hinners	August 9, 1966
Project Apollo - Communications, Command, and Telemetry System - Analysis of Character Transfer and Interrupt Processing Functions, Memorandum for File, R. M. Marella, Bell Telephone Laboratories	August 9, 1966

TITLE	DATE
Venus Swingbys for Manned Mars Missions During the 1978-1986 Period Memorandum for File, A. A. VanderVeen	August 9, 1966
Martian Atmosphere Experiments for Early Missions, Memorandum for File, F. G. Allen, P. L. Chandeysson, A. E. Hedin	August 10, 1966
Radiation Shielding Needed for Extended Interplanetary Missions, Memorandum for File, R. H. Hilberg	August 11, 1966
Saturn IB Modifications Required to Support the Orbital Workshop Mission, Memorandum for File, M. S. Feldman	August 12, 1966
Lunar Orbiter Data Screening at Langley Research Center, Memorandum for File, D. D. Lloyd	August 16, 1966
Astronomical Timeline for 1975 Twilight Mars Flyby Mission, Memorandum for File, H. S. London	August 17, 1966
Manual Guidance to Circular Orbit, Memorandum for File, W. G. Heffron	August 18, 1966
Photography of Mars Near Encounter on a Flyby Mission, Memorandum for File, D. B. James	August 19, 1966
Man-Machine Interface Problems On Planetary Flybys, Memorandum for File, R. T. Kleiner, J. M. Nervik, P. S. Schaenman	August 23, 1966
Automation Development for SC Checkout, Memorandum for File, V. Muller	August 25, 1966
Review of CSM Emergency Detection System at NAA, July 28, Memorandum for File, T. F. Loeffler	August 25, 1966
LM A-S/Half-Rack Configuration for ATM Solar Astronomy Experiments, TM-66-1013-11, D. J. Belz	August 26, 1966
Analysis of Additional Communications Coverage that Could be Obtained by Unified S-Band Stations at Canton Island, Kano, and Tananarive, TM-66-2021-10, J. P. Maloy	August 30, 1966

TITLE	DATE
AS-204 Design Certification Review - Mission Description, Mission Objectives, Launch Vehicle, Launch Complex, Briefing Book	September, 1966
Review of the Apollo Electromagnetic Compatibility Program, TR-66-320-1, A. G. Weygand	September 1, 1966
Comparison of Candidate SAA Experiment Support Modules TM-66-1013-10, G. M. Anderson, D. J. Belz, P. W. Conrad, B. D. Elrod, W. W. Hough, J. Kranton, R. K. McFarland, T. C. Tweedie, J. E. Waldo	September 9, 1966
Configuration and Interface Description for ATM on a CSM/Rack, TM-66-1013-12, W. W. Hough	September 12, 1966
A Study on the Use of an Extendible Boom as an Antenna/ Homing Guide for Lunar Base Communication/ Navigation Systems, Memorandum for File, C. E. Johnson	September 12, 1966
Analysis of Communications Between the Apollo Space Vehicle and the MSFN During the Post Injection Phase of the Lunar Mission, TM-66-2021-12, H. Pinckernell	September 15, 1966
Study of the AM for Support of Applications - A Group of Experiments, TM-66-1013-14, T. C. Tweedie, Jr.	September 15, 1966
AS-204 Design Certification Review - Mission Operations, Spacecraft, Briefing Book	September 16, 1966
Unified S-Band Tracking and Communications Coverage of the Manned Space Flight Network During Eighteen Earth Revolutions at 105 NM Altitude for Launch Azimuths at 72, 80, 90, 100, and 108 Degrees, Memorandum for File, J. P. Maloy	September 20, 1966
Apollo Lunar Drill - A Back-up Experiment for AS-504 and AS-505, Memorandum for File, N. W. Hinners	September 22, 1966
ALSEP Environmental Specification Revision: Lunar Dust, Memorandum for File, N. W. Hinners	September 22, 1966
The Lunar Landing Training Vehicle - Effect of Local Meteorological Conditions: Houston, Memorandum for File, V. J. Esposito	September 23, 1966
Improvement to the Secant Method, Memorandum for File, J. J. Schoch, R. T. Yuill	September 27, 1966

TITLE	DATE
Procedures for Management Control of Computer Programming in Apollo, TR-66-320-2, B. H. Liebowitz, C. S. Sherrerd, E. B. Parker, III	September 28, 1966
Atmospheric Braking of an Unmanned Mars Orbiter, Memorandum for File, D. E. Cassidy	September 29, 1966
Status Report: On-Pad Crew Safety, Memorandum for File, P. R. Knaff, L. G. Miller, M. M. Purdy	September 29, 1966
Secant Hypersphere Approximation of "Gradient Methods" for n-dimensional Function Optimization, TM-66-1021-5, P. F. Long, J. J. Schoch	September 30, 1966
Summary of Communications and Tracking Coverage Memoranda, TM-66-2021-11, J. P. Maloy	September 30, 1966
A LM Powered Descent Strategy, Memorandum for File, F. Heap	September 30, 1966
A Concept for Handling and Launching Large Solid Rockets, TR-66-330-2, G. W. Craft, A. W. Starkey	September 30, 1966
Flight Performance Estimate for SAA Mission 209, Memorandum for File, K. E. Martersteck	September 30, 1966

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